PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Electrical Loudspeakers

I, MINISTER OF TECHNOLOGY (formerly Aviation), London, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to electrical loudspeakers.

In sound reinforcement systems it is often desirable to employ loudspeakers having particular directional characteristics. One situation frequently met is that in which it is desired that the loudspeaker should radiate as well as possible in the direction of the audience, but should give a substantially reduced output in the direction of the microphone, thus permitting a higher degree of sound reinforcement to be achieved without acoustic feedback occurring than would be possible with an omnidirectional loudspeaker.

Horn loudspeakers are well known, and provide a basically unidirectional response both horizontally and vertically. However, if this unidirectional response is to be well maintained down to, say, 200 c/s, the mouth of the horn must have dimensions of several feet, which leads to a cumbersome structure, often incapable of being blended satisfactorily with the architectural surroundings.

In recent years, column type sound reinforcement loudspeakers, otherwise called line-source loudspeakers, have come into wide-spread use. These ordinarily consist of a wooden box several feet long, but of relatively small width and depth, containing a row of small moving-coil loudspeaker units. In the simplest arrangement, the box is closed at the back and sides, and the loudspeaker units are fed with equal signals all in the same phase. With the column placed vertically, such a system has a vertical polar diagram whose main lobe is quite narrow, but horizontally the radiation is approximately omni-directional, except at the higher frequencies where the width and depth of the box become comparable with the wavelength, the forward response then being greater than that at the rear.

In outdoor installations, when it is possible to place such a loudspeaker well above or below the microphone, a large degree of discrimination against unwanted acoustic feed-back to the microphone is afforded by the directional characteristics of the loudspeaker. In indoor installations, the reduction in unwanted feedback is much less, because of the adverse effect of reflections from the walls, floor and ceiling, but the use of a directional loudspeaker is still well worth-while. It also gives improved intelligibility by reducing the ratio of reverberant to direct sound.

Quite frequently it is impracticable to avoid placing the loudspeaker at about the same level as the microphone, and it is then not possible to exploit the loudspeaker directional characteristics to the full advantage, even outdoors. Nevertheless, the use of a column loudspeaker does confer some advantage even under these circumstances, largely for the following reasons.

When sound is radiated from a long vertical sound source, equally energised in the same phase over its whole length, the expansion of the sound wave in the vertical plane is much less rapid than for a point source, this condition holding typically out to distances of some tens of feet. Consequently the attenuation of sound intensity with distance is considerably less rapid than would be predicted by the inverse square law, so that, for a given sound intensity at a large distance, the sound intensity relatively close to the loudspeaker is lower than would be the case when using a

small loudspeaker to which the inverse square law more closely applied, thus helping to reduce acoustic feedback tendencies.

To obtain the greatest freedom from acoustic feedback from the loudspeaker to the microphone, when the loudspeaker is at about the same height as the microphone, the loudspeaker should have a suitable horizontal polar diagram, so that the microphone can be placed in a region of minimum radiation and the audience in a region of maximum radiation.

One known technique for producing horizontal directionality at low frequencies in a vertical column loudspeaker is to leave the back of the box open, and place within the box an optimum amount of sound absorbent packing, such as mineral wool. Backward radiation is largely cancelled out because the transit time of the sound through the packing from the back of the diaphragm is arranged to be approximately equal to the transit time from the front to the back via the longer path round the outside of the box. The sound pressures caused by the radiation from the front and rear of the diaphragm are thus 180° out of phase at the back of the box and largely cancel out. An appoximation to a cardioid polar characteristic is thus obtained at low frequencies.

According to the present invention there is provided a column type loudspeaker consisting of a plurality of loudspeaker units arranged in a linear array with substantially no box or baffle from the acoustic point of view and including means for reducing the output of the outer units relative to the centre units and making the reduction more pronounced as the frequency rises.

In other words the line of loudspeaker units is held in place by suporting means offering a minimum of acoustic obstruction. If, for practical reasons, the units are mounted against board having suitable holes cut in it, then this board should preferably be no wider or thicker than is necessary to provide sufficient mechanical strength.

A preferable method of holding the units in place, however, is to fix them by their magnets to a suitable strip, or strips, of wood or other material, the front part of the units then being quite unobstructed. To improve the apprearance of the loudspeaker, a casing may be added, but it should be made of expanded metal or some other material which will offer little obstruction to the sound. Alternatively the units may be fixed directly to the casing, no separate supporting members being employed.

A column type loudspeaker according to the present invention thus functions as an accoustic doublet source, giving, with the column vertical, a figure-of-eight type of horizontal polar diagram. This behaviour is maintained over a wide frequency range, though at frequencies well over 1,000 c/s the shape of the diagram becomes more complex, the rear response becoming less than the front response.

The use of a single moving-coil loudspeaker unit without any box or baffle has generally been found unsatisfactory in the past, because of the excessive loss of bass response which results. If this loss is corrected by a suitable electrical equalised, then the frequency response may be made level down to quite low frequencies, but the maximum accoustical output power obtainable at these low frequencies is severely limited by the maximum amplitude of diaphragm vibration which can be obtained without excessive non-linearity and the accompanying unpleasant intermodulation distortion. This feature, coupled with the increased amplifier rating required, has caused such methods of operating a moving-coil loudspeaker to be generally rejected.

With a column loudspeaker made in accordance with the present invention, however, several circumstances combine to overcome, in large measure, the shortcomings of single-unit doublet systems, as follows:—

(a) The total acoustic output power is produced by a considerable number of moving-coil units, thus greatly reducing the vibration amplitude necessary in each unit.

(b) The acoustic load impedance presented to each unit is increased, especially at low frequencies, by the presence of the other units, thus further reducing the necessary vibration amplitude.

(c) In speech reproduction, there is little power at the lowest audio frequencies, again helping to keep down the amplitude required.

For these reasons it is found that quite large speech volumes, suitable even for outdoor public address work, can be satisfactorily produced by loudspeakers according to the present invention, whilst for most indoor speech applications there is power handling capacity to spare.

Embodiments of the invention will be described by way of example with reference to the drawings filed with the Provisional Specification in which:

Figure 1 is a perspective view of a loudspeaker array embodying the invention;

Figure 2 is a sectional view of another loudspeaker array embodying the invention;

Figure 3 is a cut-away perspective view of the loudspeaker array of Figure 2;

Figure 4 is a horizontal polar diagram for the array of Figure 1;

Figure 5 is a graph of frequency response;

Figure 6 is a circuit diagram of an equaliser circuit suitable for the array of Figure 1;

Figure 7 and Figure 8 are graphs of frequency response; and

Figure 9 is a circuit diagram of a loudspeaker array embodying the invention.

In Figure 1 loudspeakers 1, 3, 5 are supported by their magnets being sandwiched between two strips 7, 9 of wood or other rigid material. The strips are held tight by bolts 11. In this case the front part of the array is completely unobstructed. A casing may be added to improve the appearance of the array, but this casing must offer little if any obstruction to sound.

An alternative construction is illustrated in Figures 2 and 3. Sheets 13, 15, 17, 19 of perforated or expanded metal surround the loudspeaker units such as 1. The sheet 15 supports the units and the sheets 13 and 17 are for appearance. The edges of the sheets may be fastened to strips 21 of wood or other material and this may be covered on the outside with a strip 23 of material which also serves to hold the array together. A top piece 25 may conveniently be provided.

In both the above embodiments the loudspeaker units used should preferably be of the elliptical variety, the major axes being along the line of the column. This gives a better approximation to a narrow line source than can be obtained with an equal number of circular units.

Figure 4 shows the measured horizontal polar response at 1,000 c/s for a straight vertical column constructed as described with reference to Figure 1 and employing nine approximately 9 ins. × 6 ins. units. The units were of 15 ohm nominal impedance, and were connected in groups of three, in a series/parallel arrangement, to give a total impedance of 15 ohms. The microphone distance was 24 ft.

Figure 5 is a graph showing the frequency response obtained on axis, with the microphone at 24 ft, when no equalisation was applied.

Figure 6 is a circuit diagram of an equaliser circuit designed for insertion between a power amplifier having a negligibly small output impedance and a loudspeaker array such as is described above.

Figure 7 is a graph showing the axial frequency response obtained with the equaliser in use. The gradual bass fall-off may be corrected, if desired, by inserting a simple C—R bass-lift circuit at some convenient point in the amplifier chain, this C—R circuit being +3dB at about 500 c/s and tending towards a 6dB/octave rate of rise at low frequencies. The frequency response obtained with this extra equalised in use is shown in Figure 8.

The method of preventing the polar diagram becoming too narrow at high frequencies is to arrange that, as the frequency rises, the output of the outer loudspeaker units is gradually reduced relative to that of the central units, thus giving a reduction in the effective length of the column with increasing frequency. This may be done with suitable frequency-sensitive electrical circuits.

Loudspeakers made as described above may be further refined by making the column curved (e.g. convex) instead of straight, thus preventing the vertical polar diagram from becoming excessively narrow at high frequencies. This technique, however, results in the horizontal polar diagram assuming a much more complex form, except at very low frequencies, and since a curved column is also much more difficult to construct, other methods of widening the polar diagram at higher frequencies are preferred.

Figure 9 is a circuit diagram of a loudspeaker array embodying the invention, and which achieves in an economical manner both a progressive reduction in the effective length of the column with rising frequency and a reduction in the magnitude of the side-lobe response. Nine loudspeaker units LS1, LS2, LS3, LS4, LS5, LS6, LS7, LS8 and LS9 are connected in that order in series across terminals A, B. The loudspeaker units LS1, LS2, LS3, LS4, LS6, LS7, LS8 and LS9 are shunted with resistors R1, R2, R3, R4, R6, R7, R8 and R9 respectively. The resistors have the following values:

R1, R9	1 ohm
R2, R8	2 ohms
R3, R7	5 ohms
R4, R6	10 ohms

The nominal impedance of each speaker LS1—LS9 is 3 ohms, and the impedance across the terminals A, B is therefore about 15 ohms.

The action relies on the variation in impedance of a moving-coil loudspeaker. Thus at low frequencies (e.g. 200 c/s), where the loudspeaker units have a fairly frequency-independent impedance of about 3 ohms, the effect of the resistors is simply to reduce the output from the outer units and increase that from the central units. At high audio frequencies, however, the impedance of the individual units is several times as high as at low frequencies, with the result that the major part of the voltage applied to the terminals 'A' and 'B' appears across the central unit. The effect may be made more pronounced, if desired by shunting capacitors across the outer units. The capacitance of the capacitors may be increasingly large towards the outer units.

WHAT I CLAIM IS:—

1. A column type loudspeaker consisting of a plurality of loudspeaker units arranged in a linear array with substantially no box or baffle from the acoustic point of view and including means for reducing the output of

the outer units relative to the centre units and making the reduction more pronounced as the frequency rises.

2. A column type loudspeaker as claimed in claim 1 and in which the means for reducing the output of the outer units relative to the centre units and making the reduction more pronounced as the frequency rises includes a frequency-selective electrical circuit connected to the inputs of the loudspeakers.

3. A column type loudspeaker as claimed in claim 2 and in which the loudspeaker units are moving coil loudspeakers and the frequency-selective electrical circuits includes resistors connected across the loudspeaker coils, the resistance of the resistors being decreasingly small towards the outer units.

4. A column type loudspeaker as claimed in claim 3 and including capacitors connected across the loudspeaker coils of the outer units.

5. A column type loudspeaker as claimed in any one of the preceding claims and in which the loudspeaker units are of the elliptical variety and their major axes are along the line of the column.

6. A column type loudspeaker as claimed in any one of the preceding claims and in which the column is shaped in a convex curve.

7. A column type loudspeaker substantially as hereinbefore described with reference to Figure 1, 2, 3 or 9 of the drawings filed with the Provisional Specification.

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Chartered Patent Agent,
Agent for the Applicant.

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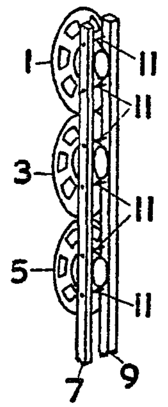


FIG. 1.

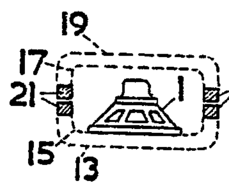


FIG. 2.

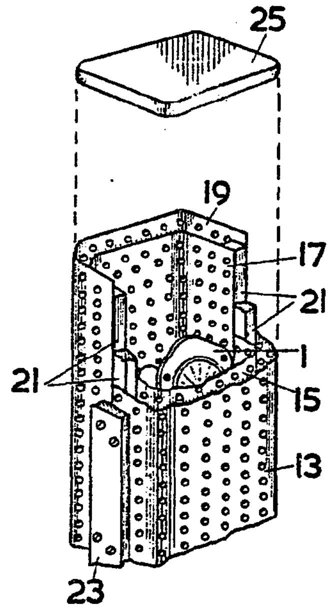


FIG. 3.

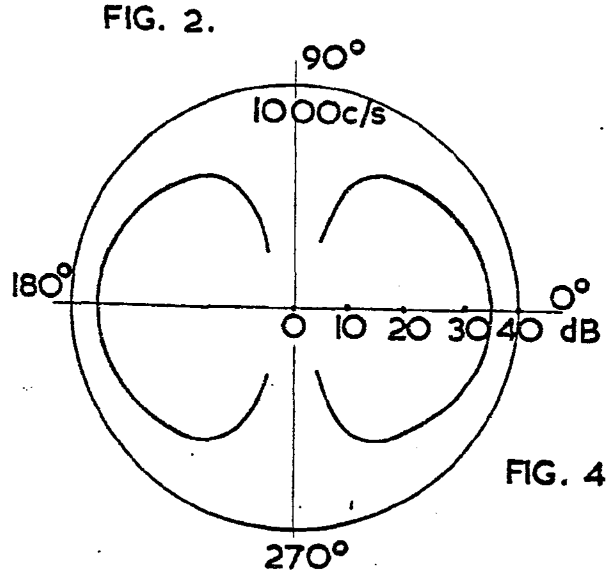
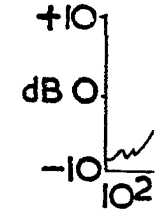
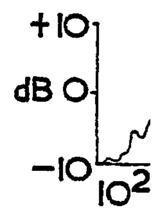
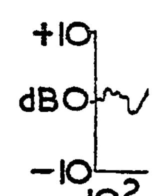


FIG. 4.







1122851 PROVISIONAL SPECIFICATION

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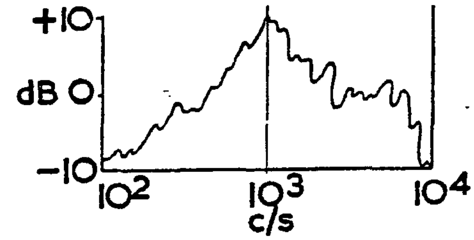
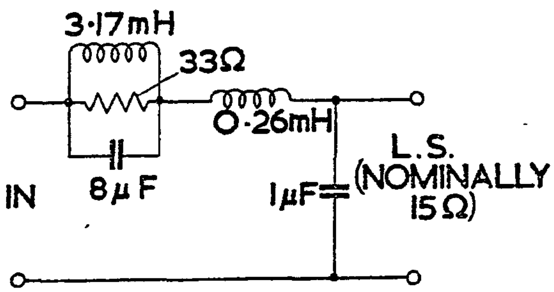


FIG. 5.



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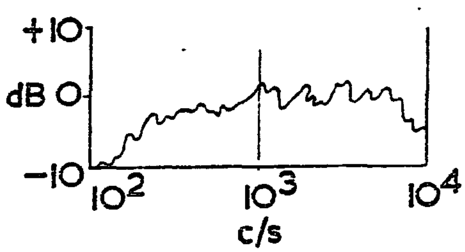

FIG. 7.

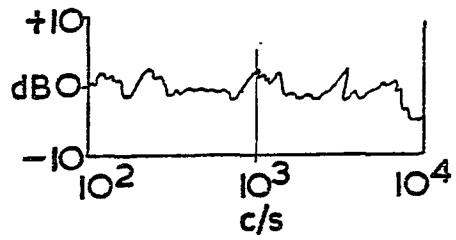

FIG. 8.

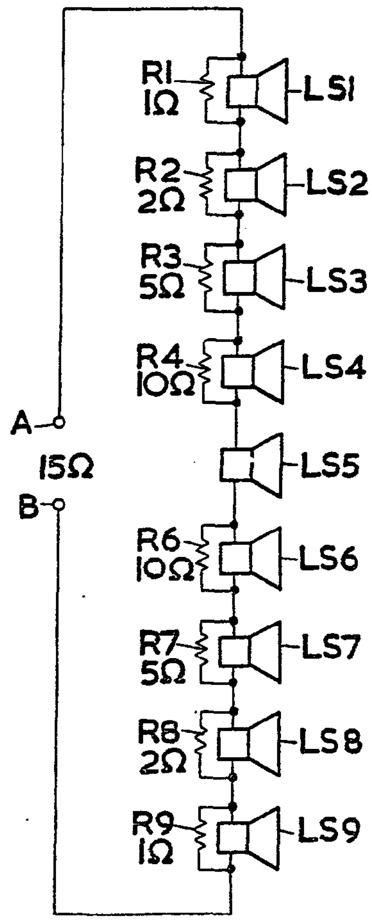

FIG. 9.

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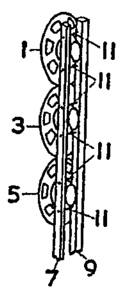

FIG. 1.

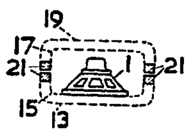

FIG. 2.

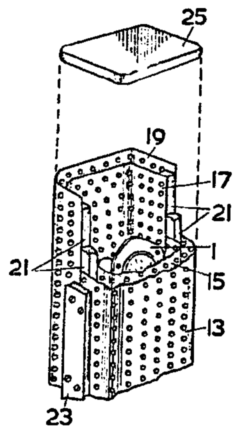

FIG. 3.

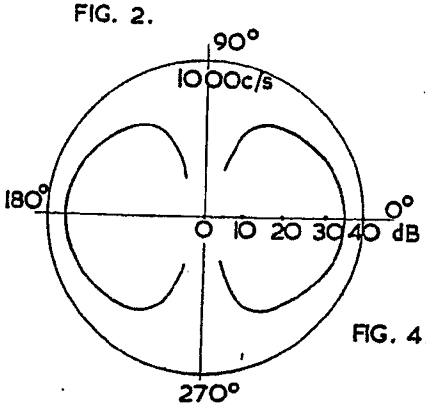

FIG. 4.

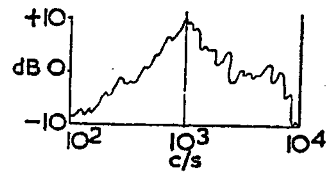

FIG. 5.

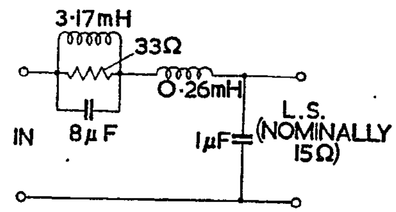

FIG. 6.

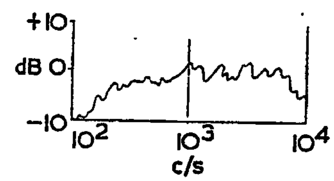

FIG. 7.

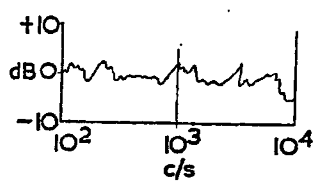

FIG. 8.

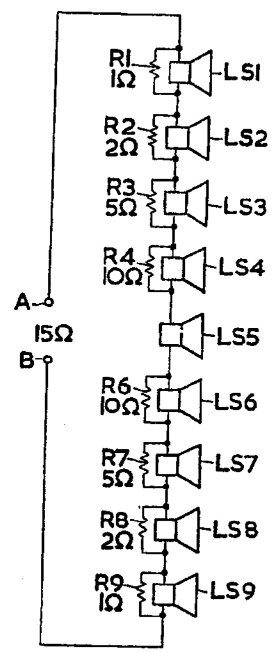

FIG. 9.